Sulphate-reducing bioreactors: current practices and perspectives

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Scope

Synopsis of key results on the operation of active sulphate-reducing bioreactors for the treatment of industrial wastewater focusing mainly on

- the selected carbon/electron donor
- the characteristics of the generated sludge
Process:
Microbially mediated sulphate reduction

- by sulphate-reducing bacteria (SRB)
- under anaerobic conditions

Process benefit:
simultaneous removal of
- sulphate
- metal ions
- acidity
- organic carbon

Physicochemical factors affecting SRB growth
- Oxygen
- Temperature
- pH
- Sulphide
- Organic acids
- Metal ions
- Oxyanions
- Competitive bacteria

Factors affecting the technological application of the process

Wastewater properties
- pH
- Temperature
- Concentration of sulphate and metal ions

Design parameters
- Reactor
- Carbon/electron source
- Organic carbon:sulphate ratio
- Hydraulic retention time
- Sulphide concentration

Flow chart
- One- or two-stage system
Bioreactors

Carbon/electron source

Most of the carbon/electron source is oxidised during energy transformation → low cell yield
Carbon/electron source selection

Lactate

\[
\begin{align*}
2 \text{CH}_3\text{CHOHCOO}^- + \text{SO}_4^{2-} &\rightarrow 2 \text{CH}_3\text{COO}^- + \text{2HCO}_3^- + \text{HS}^- + \text{H}^+ \\
\text{CH}_3\text{COO}^- + \text{SO}_4^{2-} &\rightarrow \text{2HCO}_3^- + \text{HS}^- \\
2 \text{CH}_3\text{CHOHCOO}^- + 3\text{SO}_4^{2-} &\rightarrow 6\text{HCO}_3^- + 3\text{HS}^- + \text{H}^+
\end{align*}
\]

Ethanol

\[
\begin{align*}
2 \text{CH}_3\text{CH}_2\text{OH} + \text{SO}_4^{2-} &\rightarrow 2 \text{CH}_3\text{COO}^- + \text{HS}^- + \text{H}^+ + 2\text{H}_2\text{O} \\
\text{CH}_3\text{COO}^- + \text{SO}_4^{2-} &\rightarrow \text{2HCO}_3^- + \text{HS}^- \\
2 \text{CH}_3\text{CH}_2\text{OH} + 3\text{SO}_4^{2-} &\rightarrow 4\text{HCO}_3^- + 3\text{HS}^- + \text{H}^+ + 2\text{H}_2\text{O}
\end{align*}
\]

Acetate

\[
\begin{align*}
\text{CH}_3\text{COO}^- + \text{SO}_4^{2-} &\rightarrow \text{2HCO}_3^- + \text{HS}^- 
\end{align*}
\]

Acetate oxidation is critical process step because it controls generated alkalinity, generated sulphide, final organic carbon content and at high concentration and low pH, acetate may inhibit sulphate-reducing activity.

Carbon:sulphate ratio

- Sulphate reduction should not be limited due to carbon/electron donor deficit
- Available organic carbon should be sufficient for sulphate reduction and bacterial growth/maintenance
- Carbon:sulphate ratio should be kept low, in the range favouring SRB activity
- Effluent organic carbon content should be minimised

The optimum ratio significantly depends on the composition of the bacterial culture and the selected carbon source/electron donor; that is the bacteria-substrate affinity.
Sludge fate

Metal ion sequestering - Sludge formation

Prevailing mechanism: bioprecipitation of metal sulphides

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<th>is due to</th>
<th>provides for</th>
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<tr>
<td>• extremely low solubility of most metal sulphides</td>
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<tr>
<td>• wide stability range of many metal sulphides</td>
<td>• quantitative sequestering of various divalent metal ions</td>
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<td>• precipitation under acidic pH values</td>
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<td>• selective precipitation of metals from mixed metal-bearing solutions</td>
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<td>• control on particle size → settling properties</td>
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Perspectives

- maximum carbon source utilisation and minimum organic carbon content in the effluent
- selective precipitation of metal ions and recovery of metal values of interest
- synthesis of metal sulphide nanocrystals by controlling particular parameters of the process

Thank you!